Economic Analysis of Broadleaf Afforestation

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1. Background

Tree species requirements for afforestation are set out in the Forest Service Forestry Schemes Manual and in more general terms in the Rural Development Plan 2000-2006 which sets a target of 30% broadleaf planting by the end of 2006. Tree species requirements for reforestation are less well defined. The Draft Forest Management Standard for the Republic of Ireland[1] sets out a minimum 10% area broadleaf requirement under Principle 10 Plantations.

The case for more broadleaves has been hotly debated in recent years and the NGO community is actively seeking an overall requirement for 50% broadleaves for all planting (afforestation and reforestation). The Heritage Council in its policy paper Forestry and the National Heritage[2] called for a 50:50 ratio between broadleaves and conifers.

While the level of broadleaf planting has increased in recent years and while the NGO community and others continue to lobby both at home and in Brussels for further increases, the case for broadleaves has never been subjected to any economic evaluation. This is somewhat surprising in that all sides of the debate claim to subscribe to the principles of sustainable forest management (SFM) which includes economic as well as environmental and social aspects.

This paper undertakes an initial economic evaluation of broadleaf afforestation for a range of species. As more information becomes available on prices for broadleaves and on operational and maintenance costs, the analysis will need to be redone.

2. Approach and Methodology

A range of species and yield classes were selected to represent current afforestation practice. Two sets of prices were used – the first was based on UK data while the second used the best available Irish data. Establishment costs were based on the most recent Catalogue of Operations Costs issued by the Forest Service. Felling ages were the recommended rotation ages for broadleaves based on a combination of best practice and technical (size) criteria. Forestry Commission yield tables[3] were used to estimate volumes and tree sizes. A discount rate of 5% was chosen to reflect economic sustainability. Finally for each species and yield class an economic evaluation was carried out using the discounted cash flow (DCF) approach. To compare results between species with differing rotation lengths, net present values were converted to annual equivalents. Sensitivity analysis was undertaken on broadleaf prices and discount rate.

As carbon sequestration is now recognised as a major environmental benefit of forests, an analysis is undertaken to determine the expected level of sequestration by broadleaf species.

Finally as part of the case for broadleaf planting centres on the contention that they have higher non timber value benefits than conifers, a brief discussion is presented on the current status of the evaluation of such benefits and their relevance to any form of economic evaluation.

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[1] Forest Management Standards for the Republic of Ireland. Second Draft. Prepared for "The Irish Forestry Certification Initiative" Group by Tony Mannion. December 1999.
[2] Heritage Council's Policy Paper on: Forestry and the National Heritage. The Heritage Council / An Chomhairle Oidhreachta /March 1999.
[3] Edwards P.N. 1981: Yield Models for Forest Management. Forestry Commission Booklet 48. HMSO, London

3. Economic Analysis

3.1 Discount Rate

The discount rate expresses the investor's time preference for funds. Forest economic analysis is extremely sensitive to the discount rate used. The subject of an appropriate discount rate for forestry has generated considerable comment and discussion for over 100 years.

A pre tax discount rate is used throughout this analysis, as returns from the operation of commercial woodland are currently free of tax and there is no evidence to suggest that this situation will change in the immediate future.

In traditional forest economics, the discount rate assumes that both costs and revenues increase at the same rate[4] over the life of the investment (tree crop). In doing this, the inflation rate is removed from the calculation and everything is expressed in terms of present value, i.e. in today's money

Traditionally discount rates of between 3% and 5% have been used in State forestry valuation and investment analysis in Ireland[5]. Justification for these discount rates include (a) un-quantified non-wood benefits associated with the investment, (b) social aspects associated with investment in rural areas and (c) belief that the real rate of increase in timber prices will outstrip costs by anything from 0.5% to 1.5%. More recently, Bacon[6] used a combination of 4% for public funding and 5.5% for private forest investment.

Based on the above, a discount rate of 5% was chosen for use in this economic analysis as being the most appropriate.

3.2 Timber Prices

Due to the relatively small volumes of broadleaved timber sold annually in Ireland and to the wide variation in both quality and species, there is as yet no wholly reliable database from which to develop price size curves (PSCs) for Irish broadleaves. To overcome this, UK hardwood price size data used in the analysis of restoring plantations on ancient woodland sites[7] were evaluated and compared with Irish data. .

Figure 1 shows the UK broadleaf prices. Below an average tree size of 0.5 m^3 there are no major differences between species. Even good Oak remains comparatively low in value until it reaches large dimensions when it eventually becomes the most valuable species. The report notes that "It is striking that hardwood thinnings do not break-even until around 0.3 cubic metres average stem volume, whereas conifers by this size are selling for £8 per cubic metre".

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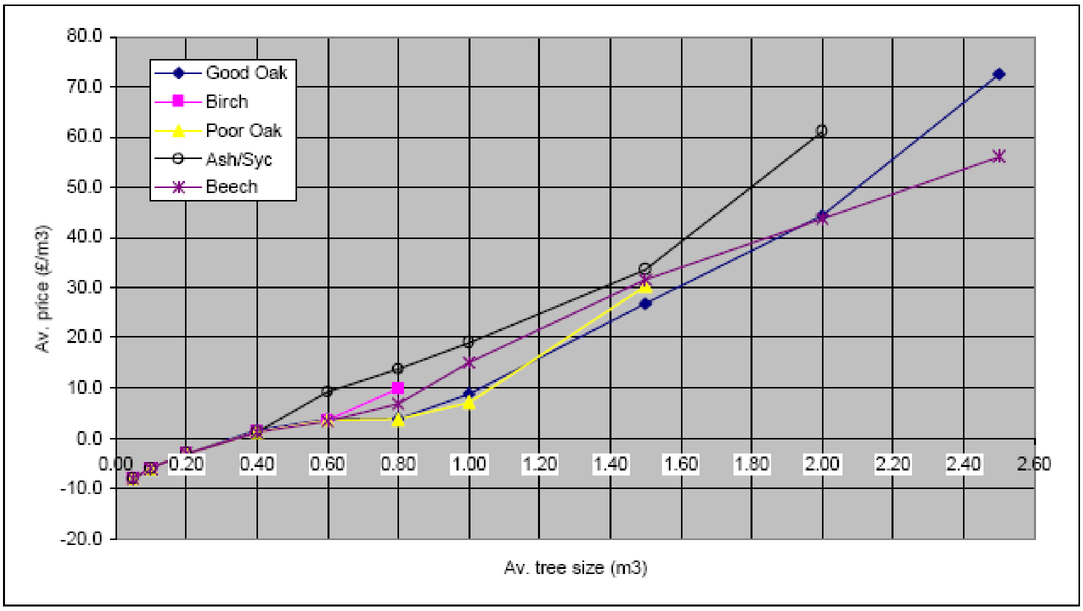
[4] It is possible however to incorporate into any DCF analysis, allowance for scenarios where either costs and / or revenues increases do not match inflation or either increase or decrease relative to the inflation rate. This is normally undertaken as part of a sensitivity analysis around assumptions on costs and or revenues.

[5] Phillips, H. 1999: Harvesting the forestry investment. IFIC Conference, "Investing in Growth", Dublin.

[6] Bacon, P & Associates. 2004: A Review and Appraisal of Ireland's Forestry Development Strategy. Stationery Office, Dublin.

[7] Pryor SN and Jackson TJF. 2001 The cost of restoring plantations on ancient woodland sites. An analysis of the economics of future management options for plantations on ancient woodland sites. Woodland Trust, UK and Oxford Forestry Institute, UK.

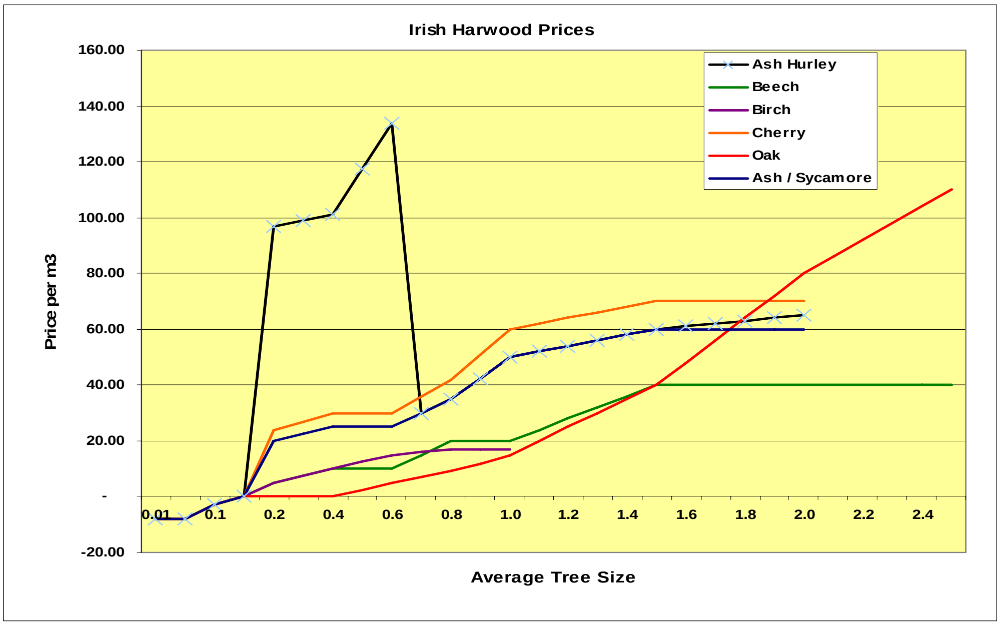
Figure 1: UK Average prices for Hardwoods (£/m3)



Source Pryor and Jackson 2001

The Irish hardwood prices used are shown in Figure 2 and are based on the prices used by Carey and O Connor[8]. The prices were determined in a similar fashion to those from the UK (E O Connor, Coillte, Cork Office pers comm.). The prices were amended to reflect a break even situation of around 0.15 m^3 average tree size. This is significantly smaller than in the UK price data but is based on the assumption of the use of improved technology for smaller dimension hardwoods into the future and higher prices for fuel wood.

Figure 2: Irish Hardwood Prices (€/m3)



Source: Based on Carey and O'Connor 2004

While there are a number of similarities between the two sets of prices as for example the prices for Oak, on average the UK prices are somewhat higher apart from Ash. Whether this difference is due to aspects of timber quality or to the presence of a more mature and competitive hardwood market in the UK is open to conjecture. In the longer term one could

[8] Carey. M. and O Connor E.2004: Towards the Development of a Strategy for old Woodland Sites. Coillte internal report.

expect that Irish prices will approximate those in the UK although this has not been the case for conifers.

Hurley Ash represents a particular Irish situation. To incorporate this into the analysis, some 20% of Ash sites were assumed to yield timber for hurley production. The hurley market is finite and thus there is a limit to the volume of material it can absorb.

3.3 Establishment Costs

The Forest Service catalogue of operation costs was used to determine establishment costs by species. Based on an average of the low and high values in Table 1, a number of species specific establishment cost models were determined. These were in all instances less than the maximum allowable costs under the current afforestation grant scheme.

Table 1: Catalogue of Operation Costs – 2005 (€/Hectare)

	Ash Sycamore		**Oak**		**Beech**	
	Low	**High**	**Low**	**High**	**Low**	**High**
Ground Preparation	425	490	490	595	490	595
Plants	630	990	1095	1430	1485	1810
Planting	380	495	595	830	690	868
Fertilizer	195	225	195	225	195	225
Filling-In	240	300	285	410	310	450
1st Cleaning	200	260	250	300	250	350
2nd Fertilizer						
Shaping	250	350	315	500	315	500
Mapping / Application	250					
Fencing	Stock / Rabbit €4.15 – 5.15					
Fire lines						
Scrub Clearance	50	200	50	200	50	200

3.5 Rotation Lengths

There are no standard rotation lengths for broadleaves in Ireland. Rotation lengths were based on a combination of (a) best practice guidance, as for example the Forestry Commission series on the management of semi-natural woodland[9] and (b) technical considerations around average tree size and species viability / vigour.

[9] Forestry Commission, 1994a. Practice Guide. The Management of Semi-natural Woodlands. 1. Lowland Acid Beech and Oak Woods. Forestry Commission, Edinburgh
Forestry Commission, 1994b. Practice Guide. The Management of Semi-natural Woodlands. 2. Lowland Beech-Ash Woods. Forestry Commission, Edinburgh.
Forestry Commission, 1994c. Practice Guide. The Management of Semi-natural Woodlands. 5. Upland Oak Woods. Forestry Commission, Edinburgh

Table 2: Rotation Ages

Species	Oak YC 6	Oak YC 4	Beech YC 6	Beech YC 4	Ash YC 10	Ash/ Syc YC 8	Birch/ OB YC 6
Rotation	120	140	120	140	60	65	65

3.6 Yield Models

For all species the Forestry Commission yield tables[10] were used to estimate volumes and average tree sizes. Standard intermediate thinning was chosen as the basic silvicultural regime. Even though the tables assume thinning intervention every five years over the rotation and this is not normal practice for hard broadleaves, it was used in the analysis rather than assume a longer thinning cycle with increased thinning volume. This latter approach has been used elsewhere[11] but requires an accurate estimation of additional mortality due to the different thinning cycle.

3.7 Economic Performance Indicators

There are two standard approaches to determining the economic performance of different tree species. The first is to use the net present value[12] (NPV) and the second is to use the internal rate of return[13] (IRR). While both of these approaches are valid, they have some shortcomings in relation to the current analysis. It is not possible to compare NPVs from projects having different timescales. Thus it is not possible to compare the NPV for Sycamore and Oak due to the widely different rotation lengths. The IRR is not particularly sensitive to changes in key parameters as for example timber prices although it is possibly better understood than the concept of NPV. Both the NPV and the IRR clearly indicate whether the project passes the basic hurdle rate which is set at 5% in this analysis.

To ensure a ready understanding by a wider audience, all NPVs were converted to annual equivalents (AE). The AE of a project expresses the present value as an annual payment over the life of the project. Thus if a project has an NPV of €5,000 at a 6% discount rate with a project life of 40 years, the annual equivalent would be €5,000 x 0.0634 or €317. This tells us that an NPV of €5,000 is the same as an annual income of €317 invested at 6%.

AEs are directly comparable thus overcoming the difficulty with rotation lengths and being based on the present value, are more sensitive to changes in key parameters than the IRR.

Annual Equivalent = NPV x (r / (1-(1/(1+r)^n) **(Equation 1)**

$$\text{Annual Equivalent} = NPV \times (r / (1-(1/(1+r)^n)) \qquad \text{(Equation 1)}$$

Where
r = Discount rate expressed as a decimal
N = Rotation length
NPV = Net Present Value

[10] Edwards P.N. 1981: Yield Models for Forest Management. Forestry Commission Booklet 48. HMSO, London
[11] Carey. M. and O Connor E.2004: Towards the Development of a Strategy for old Woodland Sites. Coillte internal report.
[12] NPV is the surplus of discounted revenues over discounted costs from a project or investment. It may be negative if costs outweigh revenues (benefits). It represents profit or return from the investment, at the given discount rate and is a measure of the projects desirability (Insley et al 1987).
[13] The IRR is the discount rate at which the surplus of discounted revenues over discounted costs is zero i.e. discounted revenues = discounted costs. The IRR is expressed as a percentage and represents the earning power of the investment.

3.8 Basic Results

3.8.1 General

The headings used in the basic economic analysis tables are as follows:-

Column 1	The tree species
Column 2	The yield class (site productivity) expressed in m^3/ha/year
Column 3	The rotation age or age of final felling
Column 4	The sum of costs (establishment + maintenance) discounted at the chosen discount rate
Column 5	The sum of timber revenues discounted at the chosen discount rate
Column 6	The net present value (Column 5 minus Column 4)
Column 7	The internal rate of return or earning power of the investment. This is the discount rate at which the sum of discounted revenues = sum of discounted costs. The IRR is the same whether for one or repeated rotations
Column 8	The NPV expressed as an annual equivalent. The annual stream of cash, which if invested at the discount rate would yield the NPV in Column 6. If the value is negative then the annual equivalent is the additional annual contribution the investor must make to bring the earning power of the investment up to the discount rate. At this point the NPV would be zero and the AE would also be zero.
Column 9	This is the average price paid per m^3. It is calculated by dividing the total revenue by the total volume (thinnings + clearfell). Note that in early hardwood thinnings revenues may be negative.
Column 10	This is the surplus of revenues over costs over the rotation. It is on a cash basis and ignores the discount rate
Column 11	This is the net cash balance in Column 12 divided by the rotation length.
Column 12	This is the age at which the sum of revenues to date equals the sum of costs to date. It is on a cash basis and ignores the discount rate.

3.8.2 Economic Analysis - Initial Findings

Table 3 outlines the results of the basic economic analyses for the range of selected species using the hurdle discount rate of 5% and Irish hardwood prices. The hard broadleaves (Oak and Beech) show very disappointing results with negative NPV values in excess of €3,000/ha. Beech would require an additional revenue stream of €230 per hectare per annum over the rotation to bring the rate of return up to the hurdle rate. A similar but slightly reduced payment would be required for Oak. The soft broadleaves perform somewhat better but still fall significantly below the hurdle rate of 5%. Ash and Sycamore show the most promise from an economic perspective.

The simple cash analysis (columns 10 to 12) shows the very difficult situation posed by broadleaves regarding the age to break even. For all broadleaves apart from Ash, break even occurs at the end of the rotation or within five years of this age. This means that the costs must be borne (by the forest owner) for extremely long periods – up to 140 years in the case of Beech – before revenues equate with costs. Again such types of cash flows are understandably unsustainable on any sort of scale. On a more positive note, all broadleaves apart from Birch show a positive cash balance over the rotation.

Table 3: Economic Analysis – Irish Hardwood Prices, Discount Rate 5%

Species (1)	Yield Class (2)	Rotation Age (3)	Single Rotation: Discounted Cost (4)	Discounted Revenue (5)	NPV (6)	IRR (7)	Annual Equivalent (8)	Average Price / m3 (9)	Cash Analysis: Net Cash Balance (10)	Cash per Annum (11)	Age Break Even (12)
Alder	8	65	3,053	758	-2,295	2.62%	-120	33.72	12,386	191	62
Alder	6	65	3,053	315	-2,738	1.52%	-143	18.91	5,079	78	65
Ash	10	60	3,050	1,803	-1,247	3.97%	-66	44.34	21,280	355	37
Ash	8	65	3,053	984	-2,069	2.99%	-108	38.29	14,550	224	51
Beech	6	120	4,508	-69	-4,577	0.94%	-230	22.80	11,310	94	130
Beech	4	140	4,508	-56	-4,564	0.35%	-228	16.68	3,066	22	140
Birch	6	65	3,053	11	-3,042	-0.27%	-159	8.32	-621	-10	NA
Oak	6	120	4,033	-30	-4,063	1.60%	-204	46.36	25,683	214	120
Oak	4	140	4,033	-57	-4,090	0.41%	-205	17.92	3,521	25	140
Sycamore	6	65	3,053	906	-2,147	2.90%	-112	37.38	14,119	217	60
Other Broadleaf	4	65	3,053	315	-2,738	1.52%	-143	18.91	5,079	78	65

The returns for broadleaves although disappointing are not untypical. The EC 2000 report[14] gives an IRR of 0.8% for Beech, Tessier and Peyron in their work on forest valuation[15] give IRR values of 0.94% to 1.71% for Oak, 1.16% to 1.56% for Beech and 0.6% to 1.86% for other hardwoods. In the UK, Pryor and Jackson[16] in their analysis give IRR values of 1% and 1.5% for Oak, 1.3% for Beech, 1.7% to 2.7% for Ash and Sycamore and -0.3% to -3.3% for Birch.

The analysis was rerun, this time using the updated UK hardwood prices and the results are shown in Table 4. The results for broadleaves are reasonably similar although due to the lower prices for Birch and the absence of a market for hurley Ash, these two species shows significantly lower returns than in Table 3.

The basic conclusion that can be drawn from Tables 3 and 4 is that whether one uses Irish or UK hardwood prices, the results are broadly the same i.e. hard broadleaf species provide a very low rate of return and considerably less than the required hurdle rate of 5%, soft broadleaves perform better but with one or two exceptions still fall short of the hurdle rate.

Table 4: Economic Analysis – UK Hardwood Prices, Discount Rate 5%

Species (1)	Yield Class (2)	Rotation Age (3)	Single Rotation: Discounted Cost (4)	Discounted Revenue (5)	NPV (6)	IRR (7)	Annual Equivalent (8)	Average Price / m3 (9)	Cash Analysis: Net Cash Balance (10)	Cash per Annum (11)	Age Break Even (12)
Alder	8	65	3,053	758	-2,295	2.62%	-120	33.72	12,386	191	62
Alder	6	65	3,053	315	-2,738	1.52%	-143	18.91	5,079	78	65
Ash	10	60	3,050	872	-2,178	3.05%	-115	36.28	16,768	279	60
Ash	8	65	3,053	154	-2,899	1.62%	-151	21.51	6,599	102	65
Beech	6	120	4,508	-69	-4,577	0.91%	-230	22.80	11,310	94	130
Beech	4	140	4,508	-56	-4,564	0.33%	-228	16.68	3,066	22	140
Birch	6	65	3,053	-244	-3,297	-2.62%	-172	0.39	-3,460	-53	NA
Oak	6	120	4,033	-30	-4,063	1.60%	-204	46.36	25,683	214	120
Oak	4	140	4,033	-57	-4,090	0.39%	-205	17.92	3,521	25	140
Sycamore	6	65	3,053	154	-2,899	2.90%	-151	21.51	6,599	102	65
Other Broadleaf	4	65	3,053	315	-2,738	1.52%	-143	18.91	5,079	78	65

[14] EC 2000: Valuation of European Forests – Results of IEEAF test applications. Eurostat, Luxemburg
[15] Tessier A. and Peyron JL. IFEN and ENGREF 1998: Faisabilité de comptes de la forêt en France. A pilot study for Eurostat and DGXI.
Tessier A. and Peyron JL. ENGREF 1999: A comparison of valuation methods for the French forests. A pilot study for Eurostat and DGXI.
[16] Pryor SN and Jackson TJF. 2001 The cost of restoring plantations on ancient woodland sites. An analysis of the economics of future management options for plantations on ancient woodland sites. Woodland Trust, UK and Oxford Forestry Institute, UK.

There are a number of factors working against broadleaves, notably higher establishment costs, longer rotations, longer wait for any positive timber revenues and poorer prices for small sized material. While it is unlikely that establishment costs could be reduced in practice significantly below the cost models used, there are arguments for either reducing the hurdle rate or increasing the price of hardwoods relative to inflation over time.

It is also unlikely that rotations could be reduced. To do so would have the impact of reducing timber revenues and if anything this would reduce the NPV and IRR values. That leaves only the possibility of reducing the discount rate and increasing timber prices.

3.8.3 Impact of Including Grants and Premium Payments

In estimating the impact of grants, a grant level of 80% of costs was assumed. This is in line with the level of payments under the EU Rural Development Regulation 2007-2013.

Table 5: Economic Analysis – Including Establishment Grants at 80%

Species	Yield Class	Discounted Costs	Discounted Revenue	Net Present Value	NPV State Investment	Annual Equivalent	Internal Rate of Return
Oak	6	966	-30	-996	3,067	-50	2.7%
	4	966	-57	-1,023	3,067	-51	1.2%
Beech	6	1,061	-69	-1,130	3,447	-57	0.9%
	4	1,061	-56	-1,117	3,447	-56	0.3%
Ash	10	761	1,803	1,042	2,289	55	6.9%
	8	764	984	220	2,289	11	5.5%
Birch	6	764	11	-753	2,289	-39	1.5%
Alder	8	764	758	-6	2,289	-0	5.0%
	6	764	315	-449	2,289	-23	3.6%
Sycamore	6	764	906	142	2,289	7	5.3%

The impact of grant payments is significant and the returns for all species are increased. In particular the IRR for Sycamore , Ash and Alder are greater than 5% which is a reasonable rate of return. However if one looks at the NPV of the state's investment and compare this with the overall NPV of the crop, the State is in effect investing more than the asset will be worth – a form of negative equity.

Table 6: Economic Analysis – Including Premiums

Species	Yield Class	Discounted Costs	Discounted Revenue	Net Present Value	NPV State Investment	Annual Equivalent	Internal Rate of Return
Oak	6	4,033	4,886	853	4,916	43	8.5%
	4	4,033	4,859	826	4,916	41	8.7%
Beech	6	4,508	4,847	339	4,916	17	6.3%
	4	4,508	4,860	352	4,916	18	6.5%
Ash	10	3,050	6,390	3,340	4,587	176	13.3%
	8	3,053	5,570	2,517	4,586	131	13.1%
Birch	6	3,053	4,597	1,544	4,586	81	13.0%
Alder	8	3,053	5,344	2,291	4,586	120	13.1%
	6	3,053	4,901	1,848	4,586	96	13.1%
Sycamore	6	3,053	5,492	2,439	4,586	127	13.1%

Premium payments were assumed to be payable for 15 years in line with the funding from 2007-2013 and not for 20 years as at present. Premiums have a more significant impact on profitability than grant payments. This is because the NPV of premium payments exceeds the NPV of grant payments. Again it can be seen from Table 6, that the State's investment is significantly greater than the NPV of the broadleaf crop.

Table 7: Economic Analysis – Including Grants and Premiums

Species	Yield Class	Discounted Costs	Discounted Revenue	Net Present Value	NPV State Investment	Annual Equivalent
Oak	6	966	4,886	3,920	7,983	196
	4	966	4,859	3,893	7,983	194
Beech	6	1,061	4,847	3,786	8,363	189
	4	1,061	4,860	3,799	8,363	190
Ash	10	761	6,390	5,629	6,876	297
	8	764	5,570	4,806	6,875	251
Birch	6	764	4,597	3,833	6,875	200
Alder	8	764	5,344	4,580	6,875	239
	6	764	4,901	4,137	6,875	215
Sycamore	6	764	5,492	4,728	6,875	247

Table 7 shows the impact of both grants and premiums. In all instances the NPV is positive and greater €3,780 per hectare. However what is more dramatic in Table 7 is not the level of return but rather the differences in NPV between the State's investment and the value of the broadleaf crop. This varies from a low of €1,247 for Ash yield class 10 to over €4,500 for Beech.

4 Forest Environmental Services

4.1 General

In the past, the main economic impact of forestry was seen as the value of timber produced and the effects of employment created in otherwise lagging regions. During the 1990s, there was a general development in forest sectors towards multiple-use policies and management with less emphasis on timber production, and more on non-timber values[17] including for example.: -

- Recreation and leisure;
- Landscape;
- Carbon sequestration (storage);
- Water regulation and water quality;
- Soil and erosion control; and
- Biodiversity and conservation.

Environmental services have been considered externalities which are not duly taken into account in resource allocation. Such market failures have resulted in under-production of watershed and biodiversity services[18].

The available research indicates that including non-timber benefits significantly augments the argument for forestry and the economic rates of return from forestry[19]. Valuation of non-market impacts enables policymakers to integrate intangible aspects of forests into decision-making. Such valuations can help in a range of decisions regarding afforestation, forest management and industry development.

Bacon[20] estimated that the total non-timber benefits of Irish forestry are currently worth €74.9 million per annum – using a mid-point value for carbon – with the potential to grow to around €126 million under the targeted planting programme, if guidelines are applied strictly. In some cases, these benefits will be realised annually in perpetuity, for example, the leisure and

[17] Liaison Unit in Lisbon (1998). Third Ministerial conference on the protection of forests in Europe.
[18] FAO (2004) Impact Assessment of Forest Products Trade in the Promotion of Sustainable Forest Management (GCP/INT/775/JPN)
[19] Pearce (1991) Forestry Expansion – a study of technical, economic and ecological factors. Forestry Commission Occasional Pape47.
[20] Bacon, P & Associates. 2004: A Review and Appraisal of Ireland's Forestry Development Strategy. Stationery Office, Dublin.

recreation benefits. In the case of carbon, these arise as long as net afforestation is taking place and further benefits should not be assigned to subsequent reforestation once the equilibrium storage level has been reached. In other cases such as bio-diversity and, potentially, landscape and heritage, the values arise in perpetuity and are likely to increase over time as average incomes rise and greater values are placed on the conservation of species, natural landscapes and heritage sites.

In a recent UK report[21] on behalf of the Forestry Commission, the annual and capitalised values of the social and environmental benefits of woodland in Great Britain was estimated as being £1.0 billion and £29.2 billion respectively with recreational and biodiversity values dominating, followed by landscape benefits,

As the Bacon report pointed out, the valuing of environmental services of forests is a complex area and there is an urgent requirement for ongoing research in Ireland to avoid reliance on results from elsewhere which are not always comparable. Notwithstanding this, environmental services have a value albeit not a traded market value, as yet.

4.2 Carbon Sequestration

The rate of carbon sequestration varies with tree species and is a function of growth rate and wood density. Dewar and Cannel[22] compared eight contrasting types of forest and woodland plantations with growth rates and other characteristics typical of UK and Irish conditions (Table 8). Species that have the fastest growth rate (higher yield classes) generally have the fastest initial rate of carbon storage. If the objective is to achieve high carbon storage in the medium term (50 years) without regard to the initial rate of storage then plantations of any species of conifer of above average growth rates would suffice. In the long term (100 years), broadleaved plantations of Oak and Beech store as much carbon as coniferous plantations.

Table 8: Carbon Sequestration Values in UK Forests {Source Dewar & Cannell (1992)}

Species	Yield Class	Rotation Age (Years)	Rate of C storage tC/ha/yr	Equilibrium C storage tC/ha
Beech	6	92	2.4	200
Lodgepole pine	8	62	2.5	155
Oak	4	95	1.8	154
Poplar - unthinned	12	26	7.3	212
Scots pine	10	71	2.7	178
Sitka spruce	12	59	3.0	167
Southern beech	16	28	4.6	179
Willow – coppice	-	8	5.9	93

The values in Table 8 have been adjusted to allow for compliance with species policy, rotation policy, open space requirements for biodiversity enhancement and timber stocking. A further reduction of the order of 10% to allow for the risk associated with disease, weather and other factors has been incorporated. The average long term equilibrium value per hectare of afforestation is 130 tC and the average rate of sequestration is 2.79 tC/ha/year which equates to an average rotation length of circa 47 years.

[21] The Social and Environmental Benefits of Forests in Great Britain. Report to Forestry Commission, Edinburgh. Kenneth G. Willis, Guy Garrod, Riccardo Scarpa, Neil Powe, Andrew Lovett, Ian J. Bateman, Nick Hanley, and Douglas C. Macmillan. Centre for Research in Environmental Appraisal & Management University of Newcastle. July 2003

[22] Dewar, R.C. and M.G.R. Cannell. 1992. Carbon sequestration in the trees, products and soils of forest plantations: an analysis using UK examples. *Tree Physiology* 11: 49-71

Table 9: Long Term Equilibrium Carbon Storage Estimates

Tree Species	Seuestration Rate tC/ha/yr	Equilibrium Value tC/ha	Rotation Adjustment Rate	Rotation Adjustment Equilibrium	Stocking and Soil Adjustment Equilibriun	Final Contribution Allowing for Risk tC/ha/yr	Final Contribution Allowing for Risk tC/ha
Sitka Spruce YC 20	4.1	208	3.9	196	161	0.70	36
Sitka Spruce YC 16	3.6	192	3.4	179	147	0.61	33
Scots Pine	2.7	178	2.5	166	136	0.37	25
Oak	1.8	154	1.8	154	126	0.07	6
Beech	2.4	200	2.4	200	165	0.09	7
Willow	5.9	93	5.9	93	74	0.43	7
Poplar	7.3	212	7.3	212	175	0.53	16
Final Adjusted Average Value per Planted Hectare						**2.79**	**130**

From Table 9, it is possible once the price of carbon is known, to estimate the value of the carbon sequestered either by the average hectare or by an individual species or mixture of species.

4.3 Markets for Environmental Services

The basic requirements for environmental services markets to develop are that demand either exists or can be created, a price or value can be established for a forest ecosystem service, and that suppliers (landowners, resource managers, etc.) are able to produce and sell this service to buyers[23].

A large number of different market-based mechanisms have been promoted for trading environmental services of forests. They reflect differences in the nature of environmental services or goods and the level of market sophistication; however various intermediary mechanisms through NGOs and trust funds dominate[24].

4.4 Realising the Value of Environmental Services

At this stage, it is not possible to capture the value of the other environmental services from forests. There are no markets as yet for these services and also no truly reliable mechanism and / or data to value many of the benefits in the context of any planned afforestation.

[23] FAO (2004). Impact Assessment of Forest Products Trade in the Promotion of Sustainable Forest Management (GCP/INT/775/JPN). Impact of New Markets for Environmental Services on Forest Products Trade. Prepared by Marko Katila and Esa Puustjärvi in collaboration with Ecosecurities Ltd.

[24] FAO (2004). Impact Assessment of Forest Products Trade in the Promotion of Sustainable Forest Management (GCP/INT/775/JPN). Impact of New Markets for Environmental Services on Forest Products Trade. Prepared by Marko Katila and Esa Puustjärvi in collaboration with Ecosecurities Ltd.